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Case#96-569

Kentucky-American Water Company

Pilot Sampling Plan for Meters Older than Ten Years

June 1997

Prepared by:

EES Consulting, Inc.

A registered professional engineering corporation with offices in the Seattle and Portland metropolitan areas

EXHIBIT C

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EES Consulting, Inc.℠

June 17, 1997

Mr. Coleman Bush
Kentucky-American Water Company
2300 Richmond Road
Lexington, Kentucky 40502

Dear Coleman:

Enclosed is the final pilot sample plan based on our telephone conversation today. Also enclosed is a copy of the file on disk (Word, Version 6.0).

I have enjoyed working with you on this interesting project.

Sincerely,

Boris Prokop
Senior Vice President

BP:drr

cc: Larry Burns
Gary Saleba

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Section 1
Overview

1.1 Introduction

During the past two decades, new meter technology has been developed which allows meters to maintain higher accuracy over a longer life than older technology. Because of the change in meter technology, Kentucky-American (K-A) has been investigating the accuracy of the new technology water meters over time. The vast majority of the meters currently installed are of solid bronze housing design.

Presently, K-A tests and replaces 5/8-inch x 3/4-inch meters at ten years according to Kentucky Public Service Commission (PSC) rules. This size meter is primarily residential. This study concerns *only* the 5/8-inch x 3/4-inch size.

1.2 Plan Objectives

K-A is proposing to extend the life of the meters **beyond** ten years. In order to ensure that meter accuracy is attainable for meters older than ten years, a pilot sampling plan is proposed. The broad objective of this pilot sampling plan is to provide a means to **verify that meters left in place beyond ten years are accurate and to determine a meter life that is appropriate.** Meters older than ten years will be tested by year so that the accuracy by year can be monitored. This pilot sampling plan would start with eleven year old meters.

1.3 Plan Outline

It is proposed that the target for meter life be twenty years. However, it is important to emphasize the pilot nature of this proposal. Meter accuracy will be monitored by a rigorous statistical sample by year. If the results of the sampling plan show that meters older than ten years are not accurate after a certain age, the meter life will be set back to ten years or the length of life that is accurate. It is proposed that annual reporting to the PSC be part of this proposal so that the PSC can actively monitor the program. The PSC can halt the program at any time.

K-A proposes that in order to verify that meters are accurate over ten years, serial testing of meters by year will occur as part of a pilot sampling plan. In other words, as a set of meters turn to year 11, they will be tested. When the same set of meters turns year 12, they will be tested and into the future. One can see as one progresses through time over the next three years, that testing will rise geometrically. Table 1 provides an example of the process. This table assumes a sample size of 200.

Table 1
Sampling Levels by Year for Eleven Year Old Meters or Older for the First Three Years

Testing Year	Meter Year	Age	Sample Level[1)]
1998	1987	11	200
1999	1987	12	200
	1988	11	200
			400
2000	1987	13	200
	1988	12	200
	1989	11	200
			600

1) Assuming all groups passed; based on control group list and assuming no significant reduction in control group population. Control group population will be affected by attrition and meter testing non-replacement

There is a geometric nature of the sampling level through time. The sampling level starts at 200 in the first year and it increases by 200 per year. By the end of 10 years, approximately 2,000 meters per year would be tested. To verify accuracy, yet recognize that the sampling level can be burdensome after multi-year testing, it is proposed that if a particular vintage has passed five consecutive years, that vintage will no longer need to be tested. For example if meters of age 11 pass five years in a row, eleven year old meters would no longer be tested.

1.4 Sampling Components

This pilot sampling plan involves testing a statistically designed sample of meters to verify that the meters are performing accurately. There are three components to this procedure:

- Sample size determination
- Sampling procedure
- Test procedure

A sample of meters is utilized for testing as opposed to full-scale testing to provide a cost-effective, yet statistically reliable way of verifying meter accuracy. A sample, which can provide an accurate yet cost-effective means of measuring the meter performance, is proposed.

A determination of the size of the sample of meters for a desired level of accuracy is required first. Given a sample size, a sample procedure will be performed for sampling

the meters and tracking the testing. Finally a test procedure is proposed as a means to verify the accuracy of the meters. A definition of what constitutes acceptance or rejection of the accuracy of a year's meters will be specified.

1.5 Accuracy of Meters Ten Years and Younger

The pilot sampling plan is intended only to verify the accuracy of meters *over* ten years. Meters ten years and younger are considered highly accurate and there are sufficient safeguards to detect unusual problems with meters younger than ten years.

One important demonstration of the accuracy of meters ten years and younger is that *all* ten year old meters are tested in "as found" condition as they are retired. This is not a sample but 100% testing. The results of a study by EES Consulting dated December 15, 1995, demonstrated that ten-year old meters are highly accurate. This is provided as a separate attachment.

In addition to the testing of ten-year meters as they are retired, there are a variety of other reasons why meters under ten years are accurate. Sister companies to K-A in twenty other states buy similar meters. These sister companies can alert K-A if a certain meter type has problems.

Also, all meters bought by K-A are tested by the manufacturer with the results provided by the manufacturer. For each batch that is bought by K-A, approximately 50 meters are tested additionally by K-A. If significant numbers are found inaccurate, these batches are replaced. Meter manufacturing companies warrant their meters between fifteen to twenty years.

Lastly, with respect to meter accuracy for ten years and younger, there are a number of meters that are tested annually due to change of service, customer requested testing and other reasons. These can be utilized to verify the accuracy of those meters under ten years. As part of the K-A's regular reporting, K-A proposes to highlight the testing of these meters under ten years as a means to monitor under ten year old meter accuracy.

In one very real sense, the proposed sampling plan is superior to the current PSC mandated ten-year change out interval. Under the current regulation, meters could be pulled from service, tested, and if accurate, could be placed back in service for another ten years without further check.

1.6 Summary

To summarize, there are current safeguards in place to monitor the accuracy of meters ten years and younger. What is proposed is a pilot plan to determine the life of meters beyond ten years with respect to accuracy. Meters would be left in place beyond ten years and tested through a rigorous sampling plan. At any time, failure of a year's sample would result in that year's meters being tested in full. The pilot sampling plan is described in this document.

Section 2
Sample Design

2.1 Introduction

It is proposed that a sample of meters eleven years and older be tested to verify the accuracy of all meters over ten years old. A sample will be made of a particular age for a particular test year for meters eleven years and older. As the pilot program progresses, there will be multiple samples representing different year's meters. In order to determine the appropriate size of a sample, three pieces of information need to be specified:

- Accuracy level desired
- Confidence level desired
- Expected variation of the target population

2.2 Accuracy Level

A distinction is made in sample design between what is called the target population and the sample. A sample is a subgroup selected from the total population. A sample is used because it would be too expensive to test the whole target population. In this report, the target population is meters eleven years old or older for a particular age for a particular test year.

Accuracy desired is expressed as the percent around the mean or average of the target population that the sample mean is expected to be estimated within. In other words, the average meter registration accuracy of the sample will be within a desired percent of the actual average of all meters of that age.

Meter registration accuracy is normally reported in percent of accuracy of the meter. For instance, a 100% registration is interpreted as being totally accurate, whereas a 101% meter registration indicates a 1% over-registration.

For example, if the target population of *all* meters older than ten years *actually* averaged 99.5% accuracy, a 5% desired accuracy for a sample would result in a sample average between 94.5% and 104.5%. The key question is what is the appropriate level of accuracy for this procedure?

As background to the accuracy needed, it would be beneficial to review the current testing requirements of the PSC. The current PSC testing requirements for determining accuracy are as follows:

- At least 90% accuracy for a low flow test
- 98.5% to 101.5% accuracy for the medium and high flow test

A medium flow test is referred to as approximately 25% of maximum capacity of the meter. A high flow test is referred to as not less than 75% of maximum capacity of the meter. If a meter fails any of these tests, the meter is considered inaccurate and would be retired. The 1.5% requirement for medium and high flow is the test with the highest accuracy required.

In this case, K-A is detecting whether meter reads are over- or under-registering on the order of approximately 1.5%. In other words, if meter reads were significantly either below 1.5% or over 1.5%, this would constitute a problem. Therefore, the accuracy of the sample should be at "approximately" the 1.0% level.

2.3 Confidence Level Desired

Desired confidence level is the percent of time one would expect the accuracy levels to hold. Normally, confidence levels for most samples are on the order of 90–99%. A 99% confidence level, which is extremely high, is proposed. For a 99% confidence level and a 1.0% accuracy sample design, K-A would be within 1.0% of the targeted sample mean 99% of the time.

The importance of a high confidence level cannot be overstated. Any meter that fails the testing procedure outlined above is retired. The need for a high confidence level reflects the need to detect any meter failure.

The important caveat is that the confidence and accuracy of a sample design refer to the *average* of a sample. For example, if 50 meters were initially pulled and tested with the result being an average accuracy of 100.7%; it is possible that one of the meters may have a registration over 101.5% while the rest of the meters are near 100.7%.

2.4 Expected Variation of the Sample Population

The expected variation of population is a parameter which must be estimated. Information about the population is inferred from the sample; however, an assumption must actually be made as to the variation in the population. One does not know for sure what the variation of meter reads will be for the meters over ten years. An estimate based on the variation of meters under ten years old is utilized.

The higher the actual variation in a population, the greater the sample size. It is important therefore to be conservative and use an estimate that is on the high side. Having performed the meter analysis for those meters under ten years in the December 15th study, a variation in those meters can be extrapolated to this study. The standard

deviation of the meter reads was *at most* 1% (in many cases it was half this). A standard deviation of 1 and a scenario with a standard deviation of 2 will be utilized to determine various sample sizes.

2.5 Sample Size

To develop a sample size, a standard statistical formula was utilized. This formula is as follows:

$$n = \left(\frac{ts}{r\bar{y}}\right)^2 \Big/ \left[1 + \frac{1}{N}\left(\frac{ts}{r\bar{y}}\right)^2\right]$$

where:

n = sample size
t = t-statistic for confidence level desired
r = accuracy level desired
y = expected mean of population
N = population size
S = expected standard deviation of population

Source: William G. Cochran Sampling Techniques, Third Edition, John Wiley & Sons, N.Y., 1995, p. 70-78

Given the desired accuracy and given confidence levels and expected variation, a sample size can be developed. Various scenarios across accuracy and expected variation were developed with the formula. It was assumed that the confidence level was held at 99%. The sample sizes do not vary significantly across confidence levels.

Table 2
Sample Size at 99% Confidence

	Accuracy Levels			
Expected Population Standard Deviation	.5%	1%	1.5%	2%
2	116	29	13	10(1)
1	29	10(1)	10(1)	10(1)

(1) 10 is minimum size.

2.6 Recommendation

Because of the relatively low expected variation in the target population, the sample sizes are relatively small. Using a sample size of 50 to 100 would give a desired accuracy of less than 1%. While the ultimate test of failure is a 1.5% test, utilizing a desired accuracy level of less than 1% provides an additional margin for study at little additional cost. It is recommended that a sample size of over 100 be utilized. To be statistically conservative, a sample of 200 is proposed. This sample of 200 will be used in each test year for each age of meter eleven years and older.

Section 3
Sample, Test and Reporting Procedure

3.1 Plan Outline

This section outlines the sample and test procedure for the sample pilot program for verifying the accuracy of meters older than ten years old including reporting of the results to the PSC. The overall structure of the program is to test meters by the year in which the meter was bought for meters eleven years and older so as to monitor their accuracy. The meter bought in a particular year by K-A is considered the age of the meter. A meter bought in 1987 in 1998 would have an age of eleven.

Each year of age over ten years is considered a different test population. Meters are sampled by a year of age and tested for accuracy. A test procedure which provides rules for acceptance or rejection for a particular year's sample will be followed by K-A. Each year, K-A will provide a report on results of the samples by age of meter.

The process is demonstrated in Table 1 of Section 1 of this report. In 1998, meters installed in 1987 will be eleven years old. The sample size and test of 200 eleven year old meters will be undertaken in 1998. Given that these eleven year old meters are considered accurate by the successful passing of the test procedure, the program will continue onto the next year, 1999.

In 1999, the meters installed in 1987 will now be twelve years old and a sample of 200 will be drawn and tested. Meters installed in 1988, will now be age eleven and a sample of 200 will be tested. The total meters tested in 1999 would be 400 for the eleven and twelve year old meters in this example.

Each age meters are tested as a group. In other words, in 1999 the eleven year old meters will be treated as a group for success or failure under the test procedure separately than twelve year old meters. If both groups pass in 1999, the pilot program will continue in 2000. As one can see from Table 1, successful passing of all groups in a year leads to a geometric rise in testing levels. If meters of a particular age fail the test procedure, all meters of a failed year will be pulled.

The overall goal of meter service life is twenty years old. However, if there is failure of a year's age across test years, before the age of twenty is reached in the pilot program, a service of length less than twenty year's could be determined.

It is recognized that the pilot program testing level will rise in a geometric manner. Also, it is anticipated that enough testing history will be built up that a particular age of

meter so that it will be demonstrated as accurate. For these reasons it is proposed that if a particular age of meter passes five years consecutively of testing, the testing for that age of meter will be discontinued and that age of meter will be considered accurate. For example, if meters age eleven pass successfully in 1998, 1999, 2000, 2001 and 2002, the meters of age eleven will not be tested in 2003 and will be considered accurate beyond 2003.

It is implied that only the youngest of the meter age being considered would be eligible for this treatment. Meters age eleven would be eligible first, then age twelve and so forth. It is proposed that the pilot program would be terminated once a determination of meter service length is determined or when the program reached testing of age twenty meters.

3.2 Sample Procedure

The sample procedure would entail having on record meters that are eleven years and older and then randomly selecting 200 meters of a particular meter age in that year. A random number generator would be utilized. The meters would be removed from the customer's premise and be replaced. The meters would then be tested. The actual test procedure is outlined below. If the testing showed a significant problem in accuracy, additional meters would be tested. All meters of that age would be tested if the problems persisted. The testing of all meters of that age would provide a full set of information as to its accuracy and would be the final determination of failure. If accuracy problems were confirmed, all meters of that particular age in that year would be replaced. After testing, the meters would be discarded rather than re-installed.

Note that as a particular age of meter is tested through time, the population size will change due to loss of meters. In order to be conservative, the sample size will be maintained at 200. If the population falls below 200, sampling for that particular year of installation will terminate.

Meter testing such as the special testing of 50 meters through their life as part of an American Water Company's program and testing of other meters (such as meters pulled for non-payment), would be utilized to verify accuracy when a problem was detected.

Testing would be performed on the meters over ten years old starting in 1998. There are presently over 5,000 meters that will be eleven years old in 1998.

In 1998, the 5,000 or so meters that were installed in 1987 will be eleven years old. Under the test procedure guidelines, if the eleven-year old meters that were installed in 1987 pass the 1998 test procedure, these meters would be left in place until 1999. In 1999 there will be two ages of meter to be tested—eleven and twelve year old meters for a total sample of 400. The sampling program would continue on as outlined above.

3.3 Test Procedure

Currently, functioning meters are tested for low, medium and high flow rates. Meters which are stuck are reported outside the results since they are obviously non-functioning. The current testing procedure for low, medium, and high flow rates would be continued for the eleven-year and older meter. In order to detect deteriorating meter accuracy, a means analysis will be performed.

Meter accuracy for various flow levels will be measured by a means analysis which will be compared to the established acceptable accuracy rates for each type of test. The mean of a set of data is the same as the average. The average for the sample for a particular age and particular test year by flow test will be calculated. An average which under-registers by 1.5% or over-registers by 1.5% for the medium and the high test will be considered an indication of inaccurate meters. An average of the low test which under-registers by below 10% or over-registers by 1%, will be considered an indicator of inaccuracy.

3.4 Additional Testing

Given the detection of possible meter accuracy by the means analysis, an additional sample of 400 meters would be drawn if the initial results fail. The total sample would be 600 with 400 for the additional sample and 200 from the original sample. When an additional sample is drawn, the test results will be grouped with the original.

For the means test, an additional sample would be pulled if the average was outside of the required percentage. For example, if the test average for the high was 101.8% where the required percents are 101.5 and 98.5, an additional sample would be drawn. If the additional sample and the original sample averages in total failed the means, all the meters would be tested for that age for the test year. **The final determination of a failure of an age of meters in a test year would be the testing of all meters of that age in a test year.** If all meters are tested, the determination of accuracy would be based on the performance of all the meters of that age for the means test. Due to the need to plan a large meter replacement, sufficient time will be needed to test all meters. The means test for all the meters is simply applying the average tests outlined above. A particular age may fail for a particular test year. The pilot program will continue until there is a clear indication across years of failure.

3.5 Reporting

A report will be filed each year with the PSC. Table 3 presents the format of the report as to the summary of testing. For a particular age of meter for that test year, a summary of the means test will be presented for the original sample. This will include number of

Table 3
K-A Pilot Sample Testir 3 Program for Meters Eleven Years and Older

Original Sample Summary Table

					Mean Analysis						
					Low Flow Test		Medium Flow Test		High Flow Test		Means
Meter Age	Year Installed	Number of Meters	Meter Mfg.	Original Sample (200)	Mean	Below 10% or Above 1%	Mean	Below 1.5% or Above 1.5%	Mean	Below 1.5% or Above 1.5%	Test Accurate?

An additional sample would be pulled if the average was outside the required percents.

Additional Sample Summary Table—Total of Original and Sample

					Mean Analysis						
					Low Flow Test		Medium Flow Test		High Flow Test		Means
Meter Age	Year Installed	Number of Meters	Meter Mfg.	Original Sample (600)	Mean	Below 10% or Above 1%	Mean	Below 1.5% or Above 1.5%	Mean	Below 1.5% or Above 1.5%	Test Accurate?

An additional sample would be pulled if the average was outside the required percents.

Total Meter Test Summary Table—Total of All Meters

					Mean Analysis						
					Low Flow Test		Medium Flow Test		High Flow Test		Means
Meter Age	Year Installed	Number of Meters	Meter Mfg.	Original Sample (600)	Mean	Below 10% or Above 1%	Mean	Below 1.5% or Above 1.5%	Mean	Below 1.5% or Above 1.5%	Test Accurate?

meters tested, and the means by the low, medium and high test. There will be explicit delineation if a test fails or passes. In addition to the test summaries presented in Table 3, original testing by meter will be available in spreadsheet form as presented in Table 4.

Table 4
Testing Detail

Meter Serial Number	Date Installed	Manufacturing	Low Flow Test	Medium Flow Test	High Flow Test
Mean					

If an additional sample or all meter testing is required, results for those will also be summarized.

The report will contain a narrative describing the results. If a meter age fails, the report will present a determination of whether the pilot program should be halted and if a age of service should be set. Any failing of a meter age will trigger reconsideration of the pilot program. A summary of meter age will also be presented from a history of the pilot program. The number of years in which a meter age has passed will be presented. When a meter age has successfully passed five years in a row, this will also be explicitly noted. Meter ages which pass five years in a row will be considered accurate and will not be further tested.

In addition to the test summaries presented in Table 3, original testing by meter will be available in spreadsheet form.

Also available will be a report of the other meter testing performed by K-A. This includes meter testing of meters which change service location, customer request testing and other testing. It is possible to check their age by using their serial number. These meters will be reported as to accuracy similar to the current quarterly reports except that by the age of meter will be delineated. Since these meters do not represent a random sample, they will be presented for background purposes only.